RESPONSES TO AGENCY COMMENTS ON THE ISOLATION BARRIER ALTERNATIVES ASSESSMENT RELATED TO RADON EMISSIONS

<u>Responses to EPA General and Specific Comments related to Radon Flux</u>

1. The concept of a heating event within radiological waste combined with its effect on the radiological conditions, specifically radon flux at the surface, is complex. The specific arguments postulated in this document in relation to the heat's effect on the radiologically-impacted material (RIM) and therefore radon flux in Attachment A are well thought out and present plausible scenarios considering an event occurring is a low probability. That said, several specific comments are provided below with regards to Attachment A (Radon Flux Analysis) which warrant consideration and/or addressing in the text of this document.

Response: *We appreciate the agency's review and evaluation of the assessment and agree that, despite the limited probability of such an event occurring, a careful evaluation is necessary. Responses to the specific comments related to radon flux are provided in italics below.*

5.d. A review of the calculations presented in Appendix A suggests that the SSE would result in a temporary increase in radon emissions by 60 pCi $m^{-2}s^{-1}$ (associated with thermal expansion of gases present in the pore space of OU-1 waste) above the estimated existing level of 13.5 pCi $m^{-2}s^{-1}$. Presumably this would result in total radon emissions of 73.5 pCi $m^{-2}s^{-1}$ for a portion of OU-1 (approximately a 75 m^2 area). Although the average emissions from OU-1 are estimated to be less than the NESHAP threshold of 20 pCi $m^{-2}s^{-1}$, the potential for, and impact of, a localized and temporary spike in radon emissions should be further evaluated.

Response: *NESHAPS (40 C.F.R. Part 61) and UMTRCA (40 C.F.R. Part 192) set an average radon release rate of 20 picocuries per square meter per second (pCi/m^2/s) as the standard for the control of residual radioactive materials from inactive uranium processing sites. 40 C.F.R § 192.02 (b)(1) n.2 states: "This average shall apply over the entire surface of the disposal site and over at least a one-year period." The technical approach followed in Appendix A was designed to evaluate routine and non-routine emissions in a manner that allowed a direct comparison with that standard, where possible. While there is no intent to use the site for residential uses, application of this standard allows for a conservative assessment of exposure risk for any potential future receptor.*

Overall, based on the size of Area 1 of approximately 40,000 m^2 and an increase in radon flux over an approximately 75 m^2 portion of Area 1, on a weighted average basis, there should be a negligible effect on the overall radon emissions from Area 1. Consequently, the overall radon flux from Area 1 should continue to meet the NESHAP standard.

The request for a further evaluation is not specific. If the request is to assess human health effects from a sub-chronic exposure to a radon puff, then a first-order screening level calculation can be used to evaluate risks from that exposure. Such a calculation would be semi-quantitative in nature and start by identifying the isolated radon flux and a target receptor. Next, the radon concentration at the receptor's location would be quantified. Because the vast majority of the doses and risks associated with radon

WLLFOIA4312 - 001 - 0017788

come from its decay products (radon progeny), the concentration of radon daughter products that would be created as the emitted radon gas moves from the source to the receptor would be estimated. Concurrently, the assessment would evaluate how the receptor's behavior at the location would result in exposures. Finally, the risk of cancer incidence from the calculated mixture of radon and radon daughter products in the air would be calculated. An example of such a first-order calculation is presented below:

Radon flux- The radon flux presented by the review, 73.5 pCi/m^2/s was used in the example calculation.

Receptor description – A person spending 2000 hours per year (h/y) was selected for this evaluation in order to reflect the exposure expectation for a full-time worker.

Receptor location – The location of the receptor was set at the fence along St. Charles Rock Road (~60 meters (m) from the middle of Area 1).

Atmospheric transport – Radon concentration at the hypothetical receptor location was evaluated using the Nearfield Box Model[1] previously described and applied in Section A.I.2 of the approved Baseline Risk Assessment (EMSI 2000):

$$C = \frac{Q \square F}{H \square W \square U_m} \approx 0.03 \text{ picocuries per liter (pCi/L) Rn-222}$$

Where:

- C = *Concentration of radon-222 in ambient air (pCi/m^3)*
- Q = *Emission rate of radon-222 [5512.5 picocuries per second (pCi/s) = 73.2 pCi/m^2/s • 75 square meters (m^2)]*
- H = *Mixing height (60 m)[2]*
- W = *Width of crosswind dimension of source area (75 m)*
- U_m = *Average wind speed in open field = 0.22 • U_{10} • ln[2.5 • H] meters per second (m/sec)*
- U_{10} = *Wind speed at 10 m above ground surface (4.35 m/sec, EMSI 2000)*
- F = *Fraction of time wind blows toward exposure point (0.1 unitless which is the approximate fraction of time wind blows south to north across Area 1)[3]*

Radon daughter ingrowth – Radon gas decays as it ages. When radon-222 (Rn-222, half-life 3.82 days (d)) decays, it produces a series of short-lived radionuclides starting with polonium-218 [Po-218, half-life 3.05 minutes (min)]. Po-218 then decays and produces lead-214 (Pb-214, half-life 26.8 min). This rapid production and decay of successive radionuclides continues with Pb-214 decaying to bismuth-210 (Bi-214, half-life 19.9 min), Bi-214 decaying to polonium-214 [Po-214, half-life 1.63 microseconds (µs)] and Po-214 decaying to the more persistent lead-210 (Pb-210, half-life 22.3 years (y)). For convenience, the portion of the Rn-222 decay series with relatively short half-lives (from Po-218 through Po-214) will be collectively called "prompt radon progeny" or "prompt radon decay products" in this evaluation.

Rn-222 is an inert, noble gas. Prompt radon decay products are created as solid, electrostatically charged particles. When Rn-222 decay occurs below the surface of the ground, these solid, charged particles are drawn to and captured by nearby solid surfaces such as soil particles. Radon gas emitted from the ground surface is thus initially unaccompanied by radon progeny. This is very important

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[1] *Gas Research Institute, 1988, "Management of Manufactured Gas Plant Sites, Volume III", prepared by Atlantic Environmental Services, Inc.*

[2] *Based on an assumed rise of 1 meter for each 1 meter of horizontal distance traveled, in this case a distance of 60 meters from the center of Area 1 to the boundary of Area 1.*

[3] See *Figures 4-1 and 4-2 in the Air Monitoring, Sampling and QA/QC Plan, West Lake Superfund Site Operable Unit 1, Auxier 2014.*

because the vast majority of the risk associated with radon exposure is attributable to its progeny, not to the radon gas itself.

Rn-222 continues to decay after it is emitted from the ground to the air above the ground, and this decay produces new radon progeny in the air. The quantity of each radionuclide in this decay series is related to the half-lives of that radionuclide and all preceding radionuclides. This relationship can be expressed in the general form:

$$\frac{dN_i}{dt} = \lambda_{i-1} \times N_{i-1} - \lambda_i \times N_i$$

where:

N = the number of atoms of radionuclide "i",
n = the number of isotopes in the decay series, and
λ = the instantaneous fraction of radioactive atoms decaying per unit of time.

Expanding this equation to the specific relationship exhibited by Rn-222, Po-218, Pb-214, and Bi-214 yields:

$$\frac{dN_{222}}{dt} = -\lambda_{222} \times N_{222},$$
$$\frac{dN_{218}}{dt} = \lambda_{222} \times N_{222} - \lambda_{218} \times N_{218},$$
$$\frac{dN_{214}}{dt} = \lambda_{218} \times N_{218} - \lambda_{214} \times N_{214}, \textit{ and;}$$
$$\frac{dN_{214}}{dt} = \lambda_{214} \times N_{214} - \lambda_{214} \times N_{214}.$$

Assuming Rn-222 is the only radionuclide present at t=0, this system of homogeneous linear, first-order differential equations can be solved using standard methods, yielding the following general solution:

$$N_n(t) = N_{222,0} \cdot \left(\prod_{i=1}^{n-1} \lambda_i\right) \cdot \sum_{i=1}^{n} \left(\frac{e^{-\lambda_i t}}{\prod_{j=1\,(j \neq i)}^{n} (\lambda_j - \lambda_i)}\right)$$

Given that the initial quantity of each prompt radon decay product in air is 0 at time 0, the solution to the system of equations describing the decay of Rn-222 gas is:

$$N_{222,t} = N_{222,0} \times e^{-\lambda_{222} t},$$

$$N_{218,t} = N_{222,0} \times \frac{\lambda_{222}}{\lambda_{218} - \lambda_{222}} \times \left(e^{-\lambda_{222} t} - e^{-\lambda_{218} t}\right),$$

$$N_{214,t} = N_{222,0} \times \lambda_{222} \times \lambda_{218} \times \left(\frac{e^{-\lambda_{222} t}}{(\lambda_{218} - \lambda_{222})(\lambda_{214} - \lambda_{222})} + \frac{e^{-\lambda_{218} t}}{(\lambda_{222} - \lambda_{218})(\lambda_{214} - \lambda_{218})} + \frac{e^{-\lambda_{214} t}}{(\lambda_{222} - \lambda_{214})(\lambda_{218} - \lambda_{214})}\right)$$

And;

$$N_{214,t} = N_{222,0} \times \lambda_{222} \times \lambda_{218} \times \lambda_{214} \times \left[\frac{e^{-\lambda_{222} t}}{(\lambda_{218}-\lambda_{222})(\lambda_{214}-\lambda_{222})(\lambda_{214}-\lambda_{222})} + \frac{e^{-\lambda_{218} t}}{(\lambda_{222}-\lambda_{218})(\lambda_{214}-\lambda_{218})(\lambda_{214}-\lambda_{218})} + \frac{e^{-\lambda_{214} t}}{(\lambda_{222}-\lambda_{214})(\lambda_{218}-\lambda_{214})(\lambda_{214}-\lambda_{214})} + \frac{e^{-\lambda_{214} t}}{(\lambda_{222}-\lambda_{214})(\lambda_{218}-\lambda_{214})(\lambda_{214}-\lambda_{214})} \right]$$

Produced atoms share the same volume of air as the parent radon-222 atoms, and the activity of each radionuclide "A_i" in that volume at time "t" is the product of its decay rate (λ_i) and the instantaneous number of that radionuclide's atoms in that volume at time "t". Knowing this, the activity of each radionuclide "$A_{i,t}$" can be calculated using the following formula once $N_{i,t}$ has been determined:

$$A_{i,t} = \lambda_i \cdot N_{i,t}$$

To provide an idea of the amount of radon progeny activity in air as a function of time, the relative ingrowth as a function of time, normalized to the initial concentration of Rn-222, is depicted in Figure 1.

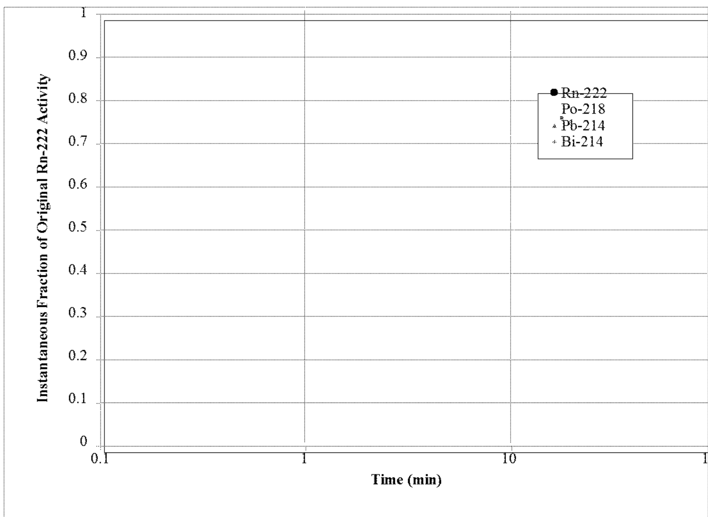

Figure 1 Normalized Rn-222 Decay and Ingrowth as a Function of Time from Rn-222 Release

Average Rn-222 progeny concentrations at the fence line. At a wind speed of 4.35 meters per second (m/s), it will take about 14 seconds (s) for freshly expelled radon gas to reach the fence line. This value has been rounded up to 15 s (0.25 min) for the remainder of this calculation for convenience. During the first 0.25 minute of travel time, some radon-222 atoms will decay, creating atoms of radon progeny. But the relatively short time afforded by movement to the fence line does not allow for much decay and therefore does not allow the concentrations of these progeny to build to more than a few percent of the parent radon-222 concentration. The combined effect of atmospheric transport to the fence and radon decay and radon progeny ingrowth were used to calculate projected air concentrations at the fence line (Table 1).

WLLFOIA4312 - 001 - 0017791

Table 1 Radionuclide Data and Projected Fence Line Concentrations

Radionuclide	Initial Concentration (pCi/L)	Half-life	Decay Coefficient, λ_i (min^{-1})	Fraction Present after 0.25 Minutes	Average Air Concentration at Fence Line[a] (pCi/L)
Rn-222	73.5	3.8 days	0.00012601	≈ 1	≈ 0.03
Po-218	0	3.05 min	0.22726137	0.055	0.0017
Pb-214	0	26.8 min	0.02586370	0.00018	0.0000054
Bi-214+Po-214[b]	0	19.9 min	0.03483152	0.000017	0.00000050

[a] *Rn-222 concentration calculated using Nearfield Box Model. Radon progeny calculated using instantaneous fractions present after 0.25 minute ingrowth period.*

[b] *Due to its relatively short half-life, Po-214's activity is assumed to be in equilibrium with that of its progenitor, Bi-214 in this evaluation:*

<u>Receptor risk estimate</u> – *Using EPA slope factors, an exposure time of 250 d/y, and an inhalation rate of 20 cubic meters per day (m^3/d), a hypothetical receptor at the fence line would inhale 5000 cubic meters (m^3) of air in a year. The incremental cancer risk estimate to such a receptor from radon emitted from the landfill during an SSE was calculated to be:*

Radionuclide	Concentration at Fenceline (pCi/L)	Intake @ 5000 m^3/y (pCi)	Inhalation Slope Factor (risk/pCi)	Immersion Slope Factor (risk·m^3/pCi·y)	Risk
Rn-222	0.03	150	3.19×10^{-11} [a]	1.62×10^{-12} [a]	4.8×10^{-9}
Po-218	0.0017	8.3	0	3.95×10^{-17}	6.5×10^{-17}
Pb-214	0.0000054	0.027	4.0×10^{-11}	1.02×10^{-9}	6.6×10^{-12}
Bi-214+Po-214	0.00000050	0.0025	3.1×10^{-11}	6.69×10^{-9}	3.4×10^{-12}
				Total Risk→	$\approx 5 \times 10^{-9}$

[a] *Because Rn-222 decay produces alpha particles but does not generate appreciable gamma or beta energy, its inhalation and immersion slope factors should then be, in theory, similar to that of Po-218. An inquiry has been submitted to http://epa-prgs.ornl.gov/radionuclides/help/issue.php regarding this apparent anomaly. Initial responses acknowledge the slope factors for Rn-222 and its progeny could be improved, but no progress by EPA is expected in the near future.*

This first order screening calculation implies that risks from this exposure scenario would be well below the 10^{-6} risk level that EPA has designated as the "point of departure" for further investigation at this and other CERCLA sites. Therefore, it is reasonable to assume that the risks at and beyond the fence line should be below the acceptable risk levels established by EPA.

If this response is accepted, the featured calculation will be refined and added to the next revision of the Radon Attachment.

51. Section 3.6.2 (Page 10, 2nd bullet of 2nd paragraph) states an increase in the emission of radon as a result of an increase in gas permeability from soil moisture vaporization. The increase in gas permeability would also increase the advective radon flux. The radon emission estimate presented in Attachment A is based on RAECOM, which appears to only estimate the diffusive flux of radon. The impact resulting from an increase in the advective radon flux should also be estimated.

Response: *Advective (bulk) movement of soil gas requires a driving force (i.e., a pressure differential) to displace the interstitial gas. Without such a driving force, the hypothetical*

WLLFOIA4312 - 001 - 0017792

changes in soil would not, in themselves, change the advective component of radon movement. Attachment A presents various postulated phenomena that could create a pressure differential between the subsurface gas and the overlying atmosphere (e.g., displacement of soil gas due to subsidence and compaction of the waste as discussed in Section 2.4.2 of Attachment A). An evaluation of potential advective transport associated with such phenomena is included as part of the calculated combined radon flux in the event that an SSE were to occur in Area 1. The results of these evaluations are presented in Section 2.6 of Attachment A.

6. One of the core concerns in regards to the concentrations of radionuclides at the site relates to the fact that the wastes accepted at the landfill contained an elevated ratio of Th-230 to uranium and radium. The uranium ore processing residues were the result of a process that was designed to separate out uranium and radium, thereby leaving thorium in the residue (Sections 2.0 and 5.4.2 of the 2008 ROD). Th-230 is the parent radionuclide for Ra-226. Th-230 was found on the surface in Area 1 at a maximum concentration of 57,000 picocuries per gram (pCi/g), while the maximum surface concentration for Ra-226 was 910 pCi/g (Table 5-2 of the 2008 Record of Decision [ROD]). The 95% upper confidence limit (UCL) for Th-230 of the arithmetic mean on the surface was 8,140 pCi/g, while the 95% UCL of the arithmetic mean for Ra-226 on the surface was 581 pCi/g (Table 7-1 of the 2008 ROD). The 95% UCL for Th-230 of the arithmetic mean at all depths was 1,060 pCi/g, while the 95% UCL of the arithmetic mean for Ra-226 at all depths was 71.6 pCi/g (Table 7-1 of the 2008 ROD).

In naturally occurring material, Ra-226 and Th-230 will be in secular equilibrium with each other. However, the sampling results, combined with the materials' history, indicate that Ra-226 and Th-230 are not in secular equilibrium at Area 1. Due to the relatively "short" half-life of Ra-226 (1,600 years) when compared with the much longer half-life of Th-230 (75,000 years), Ra-226 will effectively reach equilibrium with Th-230 in about 10,000 years. Because of this, it is important that when assessing the future risk and dose at the landfill the future concentration of Ra-226 should be considered and discussed.

The ingrowth of Ra-226 from the decay of Th-230 was identified as a concern in Section 7.2.2 of the 2000 Remedial Investigation (RI), and a sample calculation is provided for the Ra-226 concentration in Area 2 after 1,000 years. Going from the 189 pCi/g value for the 95% UCL for the arithmetic mean for Area 2, to 871 pCi/g after 1,000 years. Additionally, in Table 7-4 of the ROD the future 95% UCL concentration for Ra-226 in the surface soil and all depths for Area 1 at 1,000 years are shown to be 3,224 pCi/g and 417 pCi/g respectively. Furthermore, Table 2 of the 2011 Supplemental Feasibility study (FS) shows a summary of the Th-230 decay and Ra-226 ingrowth for Area 2. As can be seen on this table, the peak Ra-226 concentration occurs at around 10,000 years. This is further demonstrated in Figure 15 of the FS. In Appendix F of the Supplemental FS, the cover thickness calculations are verified by use of the same RAECOM web calculator referenced in Attachment A of the Isolation Barrier Alternatives Analysis document. Appendix F of the Supplemental FS uses the Ra-226 concentration at 1,000 years for the 95% UCL of all the data for Area 1 (which can also be found in in Table 7-4 of the ROD) when providing the input for the RAECOM calculator. One could argue that since the Ra-226 concentration will peak and be closer to the current Th-230 concentration in 10,000 years, the 10,000 year concentration should be used. However, radiological risk assessments are generally carried out to 1,000 years.

In all of the scenarios provided in Attachment A of the Isolation Barrier Alternatives Analysis document, the 95% UCL of the arithmetic mean for Ra-226 at all depths of 71.6 pCi/g for Area 1 (from the 2000 RI) was used without consideration of the ingrowth of Ra-226 due to the decay of Th-230. While it may be useful to consider current conditions, future concentrations of Ra-226 due to the decay of Th-230 should be taken into consideration.

Response: *The time frames associated with a possible SSE occurrence in Area 1 and increases in radium activity due to ingrowth from thorium decay are substantially different. The disequilibrium between the thorium and radium activity levels will result in an increase in radium levels over time. Calculations previously performed as part of the Supplemental Feasibility Study (SFS) indicated that peak (highest) radium levels will not occur for approximately 9,000 years (see Table 2 and Figure 15 in the December 2011 SFS report). Although for some purposes it might be appropriate to consider the future radium levels due to ingrowth of radium, this is not necessarily the case for evaluation of an SSE. While the radium levels may increase over time, the potential for an SSE will simultaneously decrease over time owing to microbial decomposition of the organic fraction of the waste materials. Inspection of the core samples obtained during the Phase 1 investigation of Area 1 indicates that over the 40 years since the waste was placed in Area 1, much of the waste material has already decomposed, resulting in a mixture of waste, decomposed waste, and soil. Continued decomposition of the waste materials is expected in the future. Continued decomposition of the waste materials reduces the amount of, and combustibility of, remaining materials, thereby reducing the potential for an SSE to migrate into or occur within Area 1. Thus, although the radium levels may increase over the next 9,000 years, the waste materials in Area 1 will simultaneously continue to decompose, thereby reducing the potential for an SSE to occur in Area 1. It is therefore appropriate to evaluate the potential impacts of an SSE under the current conditions.*

Further, as discussed in Attachment A, the radon flux from an area impacted by an SSE would have to exceed 1,560 pCi/m^2/s in order to result in an overall radon emission from the surface of Area 1 at a level that would exceed the UMTRCA limit of 20 pCi/m^2/s. An average radium-226 concentration of 1,872 Ci/g would be required to generate a radon flux of 1,560 pCi/m^2/s (See Section 2.7.1 of Attachment A). The maximum radium-226 activity level found in Area 1 was 906 pCi/g. Calculations included in the SFS indicated that the magnitude of radium-226 increases attributable to decay of thorium-230 would be approximately 13% over a period of 30 years and 44% over a period of 100 years (see Table 2 and Figure 15 in the SFS). Over the next 30 to 100 years, ongoing decomposition of the waste material will continue to decrease the combustibility of the waste such that it is unlikely that 75- or 145-year-old waste would even be able to support pyrolysis. Therefore, the levels of radium within the Area 1 landfill, even accounting for potential increases due to ingrowth from thorium, will still be less than the levels necessary to cause the radon emissions to exceed the NESHAP/UMTRCA standard over the next 30 to 100 years. These calculations are extremely conservative because they assume that no engineered landfill cover or other remedial action that would act to attenuate the radon emissions will have been implemented during this period. Evaluations of the required landfill cover thickness contained in Appendix F of the SFS report demonstrate that installation of an engineered landfill cover will greatly reduce radon emissions.

WLLFOIA4312 - 001 - 0017794

7. RIM was identified within 6 inches of the surface of Area 1 during the RI. The most elevated sample was identified on the surface. While the area identified with RIM present on the surface is smaller than that of the subsurface, any overburden thickness would be difficult to assess and in some portions of the site it is known to be zero. Attachment A assumes that an overburden exists across the site at 30 centimeters when performing the RAECOM calculations. However, when performing the calculations for the ROD selected remedy in Attachment A there is no overburden barrier assumed between the RIM and the remedy layers. The calculations for the cover thickness in Appendix F of the Supplemental FS do not calculate baseline conditions but rather mimic the ROD selected remedy calculation in Attachment A. In Appendix F of the Supplemental FS there is no assumed overburden between the RIM and the remedy. Calculation of the 95% UCL at all depths appears to include the surface sample results and is the basis of the RAECOM calculations. Section 2.2.2 of the 2011 Supplemental FS states the following:

"Radionuclides are present in surface soil (0-6 inches in depth) over approximately 50,700 square feet (1.16 acres) of Area 1. Approximately 194,000 square feet (4.45 acres) of Area 1 have radionuclides present in the subsurface at depths ranging up to 7 feet, with localized intervals present to depths of 15 feet."

Please provide an explanation as to why an overburden soil was assumed to be present for the baseline scenario and why it was assumed to be 30 centimeters.

Response: *RIM is present at the surface only in approximately 10% of the overall area of Area 1. RIM in the remainder of the site is covered with up to 7 meters of fill. The 30 cm overburden used in the model was chosen as a nominal cover depth across the entire disposal unit. It is less than the area-weighted-average depth of overburden in Area 1 and will overestimate the average radon flux in the area. Therefore, although this approach assumes the presence of some cover material over that portion of Area 1 where RIM is present at the surface and therefore underestimates emissions from approximately 10% of the area, overall it is a conservative evaluation because it assumes a thinner cover thickness over the majority of the RIM in Area 1 and therefore likely overestimates the overall emissions rate from Area 1. It should be noted that under the ROD selected remedy, a new engineered landfill cover would be installed over Areas 1 and 2 and, consequently, there would not be any RIM exposed at the ground surface.*

8. In section 2.2 of Attachment A the calculated radon flux from the current configuration of Area 1 is compared to the average measured value during the 2000 RI. It should be noted that while the average Radon Flux sample resulted in 13 picocuries per meter squared per second (pCi/m2/s), 24 samples were collected and the three highest values were 245.9 pCi/m2/s, 22.3 pCi/m2/s and one was 8 pCi/m2/s. The remainder were all below 1.9 pCi/m2/s. The mode of the data is 0.2 pCi/m2/s and the median is 0.4 pCi/m2/s. With the 245.9 pCi/m2/s value removed the average becomes 2 pCi/m2/s. Therefore the 13 pCi/m2/s average of the measured data does not compare well with the remainder of the measured data and warrants clarification.

Response: *The NESHAP and UMTRCA standards apply to the average flux from a waste disposal unit. We agree that the average of the measured values likely represents an over-estimate of the actual flux from Area 1. Therefore, the evaluation presented in Attachment A is*

WLLFOIA4312 - 001 - 0017795

conservative and likely overestimates the magnitude of a potential increase in radon emissions if an SSE were to extend into or otherwise occur in Area 1.

9. Ra-226 is a naturally occurring isotope found in varying concentrations throughout the world. The background soil concentrations determined in the RI are around 1 pCi/g. The RAECOM calculations in Appendix F of the FS assumed that each remedy layer would consist of material that contained 1 pCi/g. Background concentrations of Ra-226 in soil can easily range between 0.5 and 3 pCi/g. It would be difficult to find soils that don't contain Ra-226. However, the RAECOM calculations included in Attachment A all assume the overburden, as well as the remedy layers, contain 0 pCi/g. Please provide an explanation for assuming the overburden and remedy layers contain no Ra-226 activity.

Response: *The intent was to calculate the net radon flux as a result of the presence of the RIM. The model will be revised to include background concentrations of Ra-226 in the overburden material. The estimated impact on radon emissions under current conditions is less than 1 pCi/m^2/s. Installation of the ROD-selected remedy could result in additional radon arising from background concentrations of Ra-226 in the earth materials used to construct a landfill cover. However, this effect is expected to be minimal when combined with the overall reduction in radon emissions that would occur as a result of increased thickness and lower permeability of the engineered landfill cover. Given the minimal emissions through the ROD-selected remedy cover, the impact of any additional radon emissions from the cover materials therefore should be negligible in terms of overall radon emissions from Area 1.*

<u>Responses to USACE Comments related to Radon Flux</u>

16) Section 3.6.2. Is Subpart T (Disposal of Uranium Mill Tailings) the cited NESHAP requirement? St. Louis FUSRAP has evaluated radon releases against the 40 CFR 192.02 (b) alternate criteria of 0.5 pCi/L, which may be also be an appropriate criteria to evaluate if UMTRCA is an ARAR. This would be better criteria to evaluate what exposure there may be to members of the public, if any. Models such as CAP88, AERMOD, or RESRAD-Offsite may be helpful to demonstrate a lack of current exposure, or monitoring data taken downwind from the facility could be discussed.

Response: *The 0.5 pCi/L criterion applies to locations outside of a disposal site (please see 40 C.F.R. § 192.02 (b)(2)). This is not an absolute value but instead a limit on the incremental increase allowed outside of the disposal site. This criterion may have been used for the St. Louis FUSRAP sites because these sites were not considered to be disposal sites. In contrast, the West Lake Landfill is a disposal site, and therefore the criteria used at the St. Louis FUSRAP sites are not the appropriate criteria for the West Lake Landfill. Consequently, the NESHAP criteria for disposal sites are considered to be the relevant and appropriate requirement.*

17) Section 3.6.2. It may be helpful to note here that additional radon generation may also be present in effluent releases from the gas collection system and not solely through radon emanation from the surface as discussed in Section 4.4 of Appendix A.

WLLFOIA4312 - 001 - 0017796

Response: *We agree that radon may be present in the effluent releases of any gas collection system, but we believe that this is unrelated to the content of Section 3.6.2, "Potential Impacts if a SSE were to occur in Area 1," because there is no landfill gas collection system in Area 1.*

18) Section 3.6.2. Bullets - there were a total of 7 conclusions in EMSI's report. 5 of those conclusions appear to relate to potential impacts if an SSE were to occur of the SSE that, at a minimum, should be addressed as part of a no action consideration. This report addresses only 3 of the 5 bullets. Recommend including and addressing bullet 4 from EMSI's report: "An SSE in West Lake Area 1 or 2 would create no long-term additional risks to people or the environment." and bullet 5 from EMSI's report: "Any short-term risks would be associated with the temporary increase in radon gas coming from the surface of the landfill if no cap is installed on the landfill, or if the cap called for by the 2008 ROD was not properly maintained."

Response: *The revised report will include an appendix with calculations of potential short-term (worker and public) and long-term risks that may arise from an SSE occurring in Area 1. In order to perform such calculations, Auxier & Associates requests EPA concurrence on calculation of site-specific, aggregate slope factors for radon and its progeny using time-dependent radon-progeny equilibrium factors. The text in Section 3.6.2 will be revised to include all five bullets.*

19) Section 3.6.2. Para 4. The Flux calculations in Attachment A are compared with surface radiation measurements from the EMSI RI report in 2000. Recommend including that surface measurements will be taken to confirm calculated concentrations prior to selection of any no-action approach.

Response: *The prior RI measurements already demonstrate that Area 1 meets the NESHAP/UMTRCA standard for a disposal site. After implementation of the ROD selected remedy, an additional set of radon flux measurements are expected to be obtained to demonstrate the effectiveness of the new engineered landfill cover. Given that the RI measurements previously demonstrated that Area 1 already meets the NESHAP/UMTRCA standard for radon emission from a disposal site, it is logical to conclude that once an engineered landfill cover is placed over Area 1 it will reduce the already compliant radon emissions to an even lower level. We will include text in Section 3.6.2 stating that confirmatory measurements will be taken as part of implementation of the ROD selected remedy as required by NESHAPS.*

20) Section 2.6.2. Para 6. states that "even if these conditions were to occur, the radon emission rate from Area 1 could still be less than the standard…." then in the last sentence of the paragraph states the magnitude of radon emissions would still be less than the establishes [sic] standard…." The use of these two words seems contradictory.

Response: *The "could" in the first sentence of the paragraph will be revised to "would" so both sentences are consistent.*

WLLFOIA4312 - 001 - 0017797

23) Section 3.7. A no action alternative would still require additional monitoring to observe whether modeled radon flux corresponds to actual radon flux in the event an SSE migrates to/occurs in Area 1.

Response: *Collection of radon flux measurements from Area 1 in the event that an SSE were to migrate into or otherwise occur in Area 1 can be added to the No Action Alternative, although it is our opinion that such measurements would be unnecessary. The radon flux from Area 1 already meets the NESHAP/UMTRCA standard without any engineered landfill cover. Installation of an engineered landfill cover over Area 1 will serve to significantly reduce the already compliant radon emissions from this area. The standards of 40 C.F.R. § 192.02, and in particular footnote 1,[4] do not require post-capping monitoring to demonstrate compliance with the standards. Regardless, the description of the No Action Alternative will be modified to include possible collection of radon flux measurements from Area 1 in the event that an SSE were to ever occur in this area in the future, subject to a future determination by EPA that such measurements were necessary.*

24) Attachment 1, section 2.2. The RI states that the 95% UCL of the mean for surface radium is 581 pCi/g. Because shallow/surface material will contribute more to radon flux than subsurface material, it seems like an additional surface layer should be added to the RAECOM model.

Response: *As discussed above, RIM is present at the surface only in approximately 10% of the overall area of Area 1. RIM in the remainder of the site is covered with up to 7 meters of fill. In addition, radium-226 concentrations in all but one of the Area 1 surface soil samples (WL-106) were reported to be less than 581 pCi/g. It would not be reasonable or representative of Area 1 to add a surface layer across the entirety of Area 1 that contains 581 pCi/g of radium. It should also be noted that under the ROD -Selected Remedy, a new engineered landfill cover would be installed over Areas 1 and 2 and, consequently, there would not be any RIM exposed at the ground surface.*

25) Attachment 1, section 2.2. Though the reviewer agrees that the average flux calculated over Area 1 is 13 pCi/m^2/s and below the 20 pCi/m^2/s standard, Area 1 seems very heterogeneous, with only 1 measurement the same order of magnitude as 13 (location WL-106 at 22.3). Most flux measurements are well below this, but measurements exist ranging from 0 to as high as 246 pCi/m^2/s. Given that sample data and flux data is available for most locations it may be helpful to run the model for each location where surface flux and surface/subsurface sample data is available to determine how well the RAECOM model compares to actual site data.

Response: *The table below presents the measured radium-226 concentration and the measured and modeled radon flux values for select measurement locations. The concentration values reflect radium-226 in the first foot of soil. The parameters used to calculate the radon flux were exactly those used for the baseline conditions, but with no 30 cm overburden; that is, they are*

[4] *Footnote 1 of § 192.02 states: "Because the standard applies to design, monitoring after disposal is not required to demonstrate compliance with respect to § 192.02(a) [the longevity criterion] and (b) [the radon emission criteria]."*

based on an assumed thickness of radium bearing material of 1.4 m; a radon emanation fraction of 0.2; a porosity of 0.671; and diffusion coefficient of 1.95E-6.

Location	*Radium-226 (pCi/g)*	*Measured Rn-222 Flux (pCi/m2/s)*	*Calculated Rn-222 Flux (pCi/m2/s)*
WL-106	*906.00*	*22.30*	*291.9*
WL-111	*0.91*	*0.30*	*0.293*
WL-112	*1.32*	*1.90*	*0.425*
WL-114	*109.00*	*8.00*	*35.12*
WL-116	*0.94*	*0.20*	*0.303*

The calculated radon flux for each sample location is either comparable to or greater than the measured radon flux at each location, indicating that the model likely overestimates the radon emissions. This likely results from the use of generic site values for the model (e.g., standard layer thickness for the radon generating material, etc.) rather than values specific to each sample location.

26) Attachment l, section 2.2. It would be helpful to justify the use of 0.2 as the radon emanation fraction, as the RAECOM online instructions recommend a value between 0.2 - 0.3 and 0.2 is the low end of this value. The RESRAD default value is 0.25, which may be more appropriate.

Response: *A radon emanation coefficient of 0.2 is an appropriate, representative estimate of this parameter in soil. The use of 0.25 as opposed to 0.20 minimally increases the radon flux at the surface. For example, for the ROD selected remedy scenario, the radon flux at the surface increased from 5.7 to 7.1 pCi/m^{2}s. The radon emanation coefficient for mill tailings is 0.17; therefore, a value of 0.2 will tend to over-predict radon emanation from mill tailings. We will add the source article for this emanation coefficient value to the reference list of the report.*

29) Attachment 1, section 2.2. Area l should be better defined on a drawing (similar to Figure 4-14 of the RI) to ensure that "clean" flux measurements are not inadvertently included, see comment #16.

Response: *Additional work has been performed to better define the extent of the Area 1 waste disposal unit, and the revised boundary will be included on all future figures (for example see the figure of proposed boring locations for the Phase 1D investigation). Please also see the prior response to Comment No. 16 related to the application of the NESHAP and UMTRCA radon standard to waste disposal units.*

30) Attachment 1, section 4.5. Though a comparison to 10 CFR 20 may be helpful in the absence of other regulatory criteria, it should be noted that 10 CFR 20 effluent releases generally apply only to releases from an NRC licensee and may not be applicable at a CERCLA site. The effluent concentrations listed in Table 2 correspond to a public total dose of 50 millirem/year,

which is above those generally allowed by EPA at CERCLA Sites. Recommend you don't compare to 10 CFR 20 since EHA [sic] has a more stringent standard.

Response: *We will revise this section to remove the reference to 10 C.F.R. Part 20 limits and compare current measured radon emissions from stack gas to incremental emissions. We will not compare the stack gas emissions to any standard or criteria since we cannot differentiate the calculated RIM derived additional radon effluent of 5.74 x10-11 µCi/mL from typical background radon levels that are collected and vented by the landfill gas collection system (in the range of 1 x 10-7 µCi/mL to 1 x 10-6 µCi/mL in soil gas and 1 x 10-9 µCi/mL to 1 x 10-8 µCi/mL in flare influent).*

31) Attachment l, section 4.5. Suggest removal of the last paragraph of Section 4.5 as the release of radon into the air from stack release is not directly comparable to radon present in soil gas.

Response: *The text relating to soil gas was included to show the extreme variability of radon concentrations across Region 7. The modeled stack release is then compared to the intake stream of the Bridgeton Landfill Flare #2 gas flare stack, which is directly comparable.*

32) Attachment 1, section 4.5. 10 CFR 20 Appendix B Table 2 contains two values for radon, one for radon in 100% equilibrium and one for radon without daughters. Suggest a clarification that radon effluent releases are being compared to the 0.1 pCi/L criteria that assumes all daughters are present in equilibrium, or provide a discussion of measured/assumed equilibrium factor.

Response: *Per the response to comment 30, this section will be revised and will no longer include the comparison to 10 C.F.R. Part 20 limits. Since we are not comparing the gas stack effluent to 10 CFR 20, the comparison to Appendix B Table 2 is also removed.*

46) Section 4.6. Para 2 –recommend the specific section in Attachment A that contains the info being referenced in this text be added within the parentheses so it is easy for reader to locate the information.

Response: *We will add a reference to Attachment A, Section 4 through Section 4.6.*

50) Section 4.7. Report states, “Radon emissions from the RIM material located outside of the barrier would not result in an exceedance of the Radon NESHAP.” Because the extent of RIM has not yet been identified and because of the heterogeneity of the waste placement, recommend that this text be revised to allow for this consideration.

Response: *As discussed above, based on the RI sampling, radon emissions from Area 1 meet the radon NESHAP and UMTRCA standard. Therefore, regardless of the extent of possible RIM occurrences in the southern portion of Area 1, the overall radon emissions from Area 1 are not expected to exceed these standards. Further, the greatest thickness and shallowest occurrences of RIM, the least amount of overburden material, and highest radionuclide activity levels identified in Area 1 – and thus the materials with the greatest contribution to the overall radon*

WLLFOIA4312 - 001 - 0017800

emissions – are located in the northern and northeastern portions of this area, not in the southern portion of Area 1. The thickness and continuity of the RIM occurrences in the southern portion of Area 1 were by comparison substantially smaller, and this material occurs at substantially greater depths with substantially more non-RIM overburden than the materials located in the northern portion of Area 1. We agree that the exact limit of the occurrences of RIM containing radium and/or thorium above the unrestricted use standards has not been precisely defined relative to potential alignments for a possible thermal isolation barrier at this time. However, given that the Area 1 radon emissions already comply with the NESHAP/ UMTRCA standards, combined with overall low thickness and relatively discontinuous nature of the occurrences of RIM in the southern portion of Area 1, as well as the presence of a substantial amount of non-RIM overburden material in this area, any radon emissions that may occur from RIM located on the south side of a potential isolation barrier are not expected to result in an exceedance of the radon standard.

Setting aside these considerations, investigations of possible RIM occurrences in the western and southwestern portions of Area 1 are ongoing, and based on the priorities EPA has currently established for the site work, the results of these investigations should be available prior to preparation of a revised Isolation Barrier Alternatives Assessment and can therefore be accounted for as appropriate.

65) Section 7.6. Para 2. Potential RIM outside the barrier is not expected to pose a significant risk (see attachment A) and RIM outside barrier would not result in exceedance of Radon NESHAP. Recommend the specific section in Attachment A in which the information that supports this can be found is cited in the parentheses.

Response: *Attachment A, Section 4 will be cited in Section 7.6, Paragraph 2.*

<u>Responses to MDHSS Comments related to Radon Flux</u>

1. Attachment A, providing for radon flux estimates in the event a subsurface smoldering event (SSE) occurs, utilizes formula or model inputs that are outdated. The software package RAECOM, provided by World Information Service on Energy (WISE), is used in this document to estimate radon flux in the event of an SSE.

   The U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research provides the regulatory guide *Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers,* June 1989. This guidance appears to be the foundation for RAECOM. The International Atomic Energy Agency (IAEA) published Technical Reports Series number 474, *Measurement and Calculation of Radon Releases from NORM Residues*, 2013. This document provides updates on modeling radon emanation and exhalation from milling residues.

DHSS recommends that RAECOM calculation and modeling assumptions be appraised against the IAEA updates, to determine if RAECOM is sufficiently protective of human health. In support of the updated RAECOM results, Argonne National Laboratory's RESRAD Offsite

WLLFOIA4312 - 001 - 0017801

software should be used as an additional line of evidence to confirm the findings of the RAECOM modeling. The more stringent of the findings should be used for decision making.

Response: *We have compared the guidance contained in the IAEA document with the parameters and assumptions used in the RAECOM software. While the IAEA document did contain newer types of coverings (geotextile, etc.), the assumptions and parameters used to calculate radon flux were essentially the same as those used in the RAECOM model.*

RESRAD Offsite does not provide radon fluxes as part of its output. This information is provided in the "Detailed.rep" file generated by RESRAD Onsite. Using the same numerical values as were used in the RAECOM simulation, the RESRAD Onsite radon flux values were calculated to be within a factor of two, but higher than the RAECOM-generated radon flux values.

Regardless of the model used, all models pose some level of uncertainty. Due to this uncertainty, in the event an SSE occurs in the radiologically-impacted material (RIM), DHSS recommends that environmental samples be collected to determine if levels of radon and its progeny pose unacceptable risk to workers and the public.

Response: *Pursuant to the Administrative Settlement Agreement and Order on Consent for Removal Action – Preconstruction Work, a perimeter air monitoring network has been installed around both Areas 1 and 2 and is now operational. Monitoring of these stations includes collection of radon samples. These data can be used to evaluate potential exposure levels to onsite workers and along the property boundary where public exposure may occur.*

2. Attachment A, Figure 2-2, Average Radon Flux from Area 1 for Four Scenarios

   This figure identifies a radon flux rate of 0.29 picocuries per meter squared per second ($pCi/m^2/s$) for the "ROD Remedy with SSE". However, the document does not provide calculations to support the assumptions. DHSS recommends reviewing comment 1 above, updating RAECOM as recommended, and presenting the additional line of evidence using RESRAD Offsite. These results should be reviewed by the Missouri Department of Natural Resources and/or DHSS prior to finalizing. Again, DHSS recommends collection of environmental samples to determine if the outcome is protective of human health.

Response: *The basis for this value is presented in Section 3.5 of Attachment A. We will include a reference to the location of the calculations that support the table values. Please also see the response to Comment No. 1 above.*

WLLFOIA4312 - 001 - 0017802